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Effect of light spectra on stem cutting rooting and lavender growth

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ABSTRACT. French lavender (*Lavandula dentata* L.) is of great ornamental, medicinal, and aromatic interest. It is generally propagated vegetatively using stem cuttings. When using artificial lighting, a specific light composition can modify the entire plant phenology and is a factor that can be managed in controlled conditions. This study evaluated the rooting of stem cuttings and growth of lavender under four spectral LED lights. The LED lights used were: T0 (white LED, Roblan®), T1 (AP67 Milky, Valoya®), T2 (NS1, Valoya®), and T3 (AP673L Milky, Valoya®). The first phase evaluated the rooting of stem cuttings and initial development. The plants were then transferred to plastic pots to evaluate plant growth. In both rooting and growing phases, the plant morphological characteristics and water and light efficiencies were evaluated. Nutrient-uptake efficiencies were also evaluated after the growing phase. It was observed that cuttings rooted under the influence of T1 showed greater height. After the growing phase, plants under T3 showed better results in electricity use efficiency, water use efficiency, and nutrient-uptake efficiency and less nitrate leaching. They also presented more uniform growth with a compact canopy. Thus, T1 was better for the stem cuttings rooting phase, while T3 was better for growth and energy efficiency.

Keywords: *Lavandula dentata* L.; Lamiaceae; nutrient solution; LED; soilless cultivation; vertical farm.

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Introduction

Lavandula dentata L., commonly named French lavender, fringed lavender, or toothed lavender, is endemic to the Mediterranean basin region. Its velvety-looking leaves and violet flowers make it ornamental. The oils extracted from these plants have various bioactive compounds which expand their utility (Ouedrhiri, Mounyr, Harki, Moja, & Greche, 2017; Lesage-Meessen, Bou, Sigoillot, Faulds, & Lomascolo, 2015).

Vegetative propagation of *L. dentata* L. using stem cuttings is a common alternative to seed reproduction with high success rates (Bona, Biasetto, Masetto, Deschamps, & Biasi, 2012). Stem cutting propagation enables greater homogeneity for medicinal and aromatic plant production, avoiding genetic variability caused by seed reproduction (De, 2017). However, vegetative propagation using stem cuttings requires favorable environmental conditions or controlled environments to produce healthy and homogeneous plants in a pre-established period (Gil, Jung, Lee, & Eom, 2020). Regardless of the purpose of seedling production, rooted lavender stem cuttings spend part of their life cycle in pots (Pistelli et al., 2017), increasing the interest in studying their initial growth phase (Najar et al., 2019; Fascella, Mammano, D'Angiolillo, Pannico, & Rouphael, 2020).

Light is a primary source of energy for plants that drives metabolism and growth. Light affects plant hormone production by influencing plant metabolism. However, these changes vary among plant species (Paradiso & Proietti, 2021). As light directly affects photosynthesis, most studies have focused on plant shoots. However, interest in the influence of light on the roots has grown, either by studying a simple change in the partition of photosynthesis carbohydrates or by light signaling hormonal regulation (Gelderen, Kang, & Pierik, 2018).

Sunlight is composed of a wide range of spectra and is a natural source of light for plants. Light spectral composition is as important for plant growth as intensity because each spectrum range influences a specific plant receptor (Spalholz, Perkins-Veazie, & Hernández, 2020). It is possible to observe different plant responses depending on the light spectrum range from seed germination (Oliveira, Asmar, Silva, Morais, & Luz, 2019), growth and elongation (Li et al., 2017) to plant mass (Nájera & Urrestarazu, 2019). When natural

lighting is limited or absent, artificial lamps can assist plant growth (Bantis & Radoglou, 2019; Wei, Liu, Hu, & Jeong, 2020). Currently, this artificial light is provided using light-emitting diode lamps (LEDs), which offer the possibility of choosing specific spectra, emitting less heat, having a long life, and even growing via vertical farms (Virsile, Samuolienė, Miliauskienė, & Duchovskis, 2019).

Light supply directly affects plant growth and development. It also affects mineral nutrient dynamics. Variations in light intensity and spectrum influence nutrient absorption and accumulation (Nájera & Urrestarazu, 2019). Thus, when working with artificial light supply, one must observe the growth and the nutritional changes in the plants. Despite the importance of cultivating lavender in pots, few studies have focused on the dynamics of nutrient-uptake in these conditions (Matysiak & Nogowska, 2016).

Based on these antecedents, this study evaluated the rooting of stem cuttings and the growth of *L. dentata* L. plants under LED spectrum lamps.

Material and methods

Stem rooting and growth experiments were conducted sequentially in a growing chamber at the Laboratory of Climate Control and Soilless Cultivation, University of Almería, Spain, between April and August 2020. The temperature and relative humidity were 24°C and 80%, respectively. The photoperiod was 16/8h (day/night). All settings were the same for both experiments.

For the rooting phase, *L. dentata* L. cuttings were collected from visibly healthy adult plants in the Garden of Aromatic and Medicinal Plants of the Center for Scientific Collections of the University of Almería (CECOUAL, Universidad de Almería; 36°49'55'' N, 2°24'02'' W; 3 m.a.s.l.). The average length and fresh mass of stem cuttings were 5.8 cm (±0.24) and 352.6 mg (±22.1), respectively. Rooting took place without rooting stimulants in plastic trays with 24 cells (23 mL capacity per cell) filled with moistened coconut fiber. The trays remained on the shelves under four separate LED light treatments of different spectra. During the first 15 days, the trays were covered with plastic wrap. Fertigation was performed with the nutrient solution described by Sonneveld and Straver (1994) whenever 10% of the easily available water in the mass was lost. The rooting phase lasted for 60 days.

For the growing phase, 60 days old rooted stem cuttings were transplanted into 250 mL plastic pots (8 cm in diameter and 7 cm in height) filled with coconut fiber saturated with nutrient solution. As in the rooting phase, fertigation was performed whenever 10% mass of the easily available water was lost (Rodríguez, Reca, Martínez, López-Luque, & Urrestarazu, 2015). The growing phase lasted for another 60 days, totaling 120 days of luminous influence.

For the experimental treatments, three light-emitting diode (LED) lamps were used in an area of 0.504 m². White LED lamps (Roblan®, Toledo, Spain) were used as the control (T0) treatment. The other treatments were LEDs used in agriculture (Valoya®, Helsinki, Finland): T1 (model L18 AP67 Milky), T2 (model L18 NS1), and T3 (model L18 AP673L Milky). All lamps had the same length and wattage (18 W). The spectra of each treatment were measured with a UPRtek MK350S LED (UPRtek, Taiwan) and are shown in Figure 1 and Table 1.

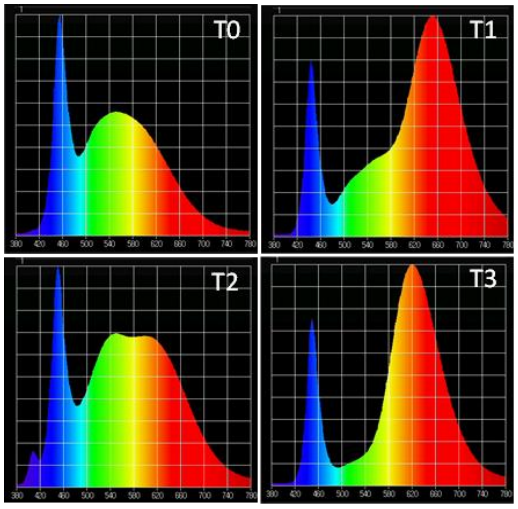

Figure 1. Spectrum profile of each LED used as a treatment during the rooting and growing phase of *Lavandula dentata* plants. T0 = Roblan® LED T8 18W; T1 = Valoya® L18 AP67 Milky; T2 = Valoya® L18 NS1 18W; T3 = Valoya® L18 AP673L Milky.

Table 1. Parameters of LED used during rooting phase and growing phase of *Lavandula dentata* L. plants.

	T0	T1	T2	T3
Illuminance (lux)	4086 ± 374b	2231 ± 106d	4685 ± 291a	3168 ± 346c
PPF (μmol m^{-2} s^{-1})	95.0 ± 10.5b	66.0 ± 3.8d	109.9 ± 5.9a	89.1 ± 10.2c
Spectral fraction (%)				
UV	0.13 ± 0.02b	0.09 ± 0.01c	0.26 ± 0.01a	0.10 ± 0.01c
Blue	26.3 ± 1.3a	12.2 ± 0.1c	20.5 ± 0.6b	12.4 ± 0.4c
Green	42.9 ± 0.5a	19.3 ± 0.5d	37.3 ± 0.4b	22.2 ± 2.0c
Red	26.9 ± 1.6d	53.3 ± 0.3b	35.4 ± 0.7c	57.5 ± 1.8a
FR	3.6 ± 0.2d	15.2 ± 0.3a	6.5 ± 0.2c	7.9 ± 0.3b

PPF = Photosynthetic photon flux. Different letters in row indicate significant differences ($p \leq 0.05$) according to Tukey test. T0 = Roblan® LED T8 18W. T1 = Valoya® L18 AP67 Milky. T2 = Valoya® L18 NS1 18W. T3 = Valoya® L18 AP673L Milky.

The sensors LP471-PHOT and LP471-PAR (Delta OHM®, Padua, Italy) were used to measure luminance (lux) and photosynthetic photon flux, PPF (mmol m^{-2} s^{-1}), respectively (Table 1).

During the rooting phase and in the growing phase, fertigation was performed with Sonneveld and Straver (1994) nutrient solution (pH = 5.8; electric conductivity, EC = 2.0 dS m^{-1}). During each fertigation, at least 20% of the volume of the applied solution was drained to avoid salinization of the substrate (Rodriguez, Reca, Martínez, Lao, & Urrestarazu, 2014). After each fertigation, drainage was collected, and the following parameters were evaluated: drainage volume, pH, EC (pH/electric conductivity LAQUAact-PC110, Horiba Advanced Techno, Japan), nitrate level (LAQUAtwin NO_3^- Meter, Horiba Advanced Techno, Japan), and potassium level (LAQUAtwin K+ Meter, Horiba Advanced Techno, Japan). Finally, the amount of water used (difference between intake and drainage) and leached nutrients (K^+ and NO_3^-) were calculated.

After 60 days, at the end of the rooting phase, stem cuttings were harvested, surviving plants were counted, and their shoot heights were measured. The harvested cuttings were divided into roots, leaves, and stems to obtain fresh and dry masses. For estimating the latter, the samples were dried in an oven at 85°C for 72h (Heratherm OGS 100, Thermo Electron, Germany). The water use efficiency (WUE) was calculated using the fresh mass/water consumed, and the results were calculated in g L^{-1} (Pirzad & Mohammadzadeh, 2018). The light parameters were used to calculate the electricity use efficiency (EUE = dry mass/electricity consumed, results in mg kW^{-1}), light use efficiency (LUE = dry mass/emitted photons, results in mg mol^{-1}), and illuminance use efficiency (IUE = dry mass/lumens emitted, results in mg lm^{-1}) (Fan et al., 2013; He, Yan, Sun, & Yang, 2020). The root-to-shoot ratio (R/S) was derived from root dry mass/shoot dry mass.

At the end of the growing phase, the potted plants were harvested. Fresh and dry masses of roots, leaves, and stems; and electricity use efficiency (EUE), water use efficiency (WUE), light use efficiency (LUE), and illuminance use efficiency (IUE) were evaluated following the same procedures as described for rooting phase. In addition, mineral nutrients in the harvested plants were determined by colorimetric method using Nessler's reagent. A spectrophotometer (Specord 210, Analytik Jena, Jena, Germany) was used to determine nitrogen levels (N), and an atomic emission spectrometer (ICPE-9000, Shimadzu, Kyoto, Japan) was used to determine phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) levels. The nutrient use efficiency (NUE = shoot dry mass/nutrient provided) and the nutrient uptake efficiency (NUpE = shoot nutrient content/nutrient provided) were then calculated for each macronutrient (García-Caparrós, Quiróz, & Lao, 2019). Finally, essential oil (EO) was extracted by hydrodistillation from the dry shoot (dried at 42°C until constant mass) in a Clevenger-type apparatus for two hours. The EO yield was expressed as a percentage of EO presente in the dried shoot (mass/mass).

The statistical design was completely randomized with four replications and four treatments (LED lights). For the rooting phase, the experimental unit was a 24-cell tray with one stem cut per cell, totaling 96 stem cuttings per treatment. For the growing phase, a 250 mL plastic pot was the experimental unit, totaling 16 pots per treatment. In both rooting and growing phases, plants were moved within the space of each treatment to mitigate any environmental variation. All data were tested for analysis of variance (ANOVA), and when significant, compared by Tukey's test ($p \leq 0.05$).

Results and discussion

The light parameters of T2 presented the highest values for illuminance and photosynthetic photon flux (PPF), while T3 exhibited the lowest values (Table 1). When compared to the control (T0), the illuminance values of T2 were 14.6% higher while the PPF was 15.7% higher, whereas the values observed for T3 showed lower average values of illuminance (22.5%) and PPF (6.2%) compared to T0. A similar variation was observed

when comparing different spectral ranges and maintaining the same energy expenditure (Nájera, Guil-Guerrero, Enríquez, Álvaro, & Urrestarazu, 2018). The spectral compositions among the LEDs also showed variations. T0 was mostly composed of blue and green bands, while the other treatments showed greater distributions of red and blue bands (Table 1 and Figure 1).

After the rooting phase period, the stem cuttings survival showed no significant difference, with an overall average of 94% (Table 2). These results can be considered satisfactory for this lavender species, which has good rooting rates even without the use of rooting stimulants (Bona et al., 2012). Survival success is often linked to the maintenance of the initial hydration (Bahedh & Habib, 2020). The survival data from plants in the growing phase are not shown here, as there was no mortality from the transplanted plants.

Table 2. Survival (%); height (cm); fresh mass and dry mass of the leaves, stem, and root (mg stem cutting^{-1}); electricity use efficiency (EUE, mg·kW^{-1}); light use efficiency (LUE, mg·mol^{-1}); illuminance use efficiency (IUE, mg·lm^{-1}); water use efficiency (WUE, g·L^{-1}); and root-to-shoot ratio (R/S) of *Lavandula dentata* stem cuttings after 60 days of rooting phase, under light treatments.

	T0	T1	T2	T3
Survival	93 ± 6.0ns	95 ± 3.8ns	89 ± 9.4ns	100 ± 0ns
Height	5.27 ± 0.58b	6.74 ± 0.25a	5.16 ± 0.83b	5.77 ± 0.52b
Fresh mass				
Leaves	578 ± 160ns	595 ± 70ns	601 ± 130ns	599 ± 80ns
Stems	168 ± 20ns	184 ± 20ns	144 ± 30ns	170 ± 20ns
Roots	463 ± 70ns	521 ± 10ns	489 ± 80ns	477 ± 40ns
Dry mass				
Leaves	109 ± 34ns	110 ± 15ns	118 ± 27ns	114 ± 14ns
Stems	59 ± 7ns	62 ± 11ns	46 ± 8ns	57 ± 11ns
Roots	74 ± 5ns	85 ± 6ns	67 ± 10ns	73 ± 11ns
EUE	241 ± 38ns	256 ± 8ns	231 ± 44ns	243 ± 19ns
LUE	76 ± 11b	116 ± 4a	62 ± 11b	81 ± 6b
IUE	6.1 ± 0.9c	11.8 ± 0.4a	5.1 ± 0.9c	7.9 ± 0.6b
WUE	11.2 ± 2.1ns	11.3 ± 1.1ns	11.5 ± 2.5ns	12.4 ± 1.1ns
R/S	0.45 ± 0.09ns	0.49 ± 0.05ns	0.41 ± 0.04ns	0.43 ± 0.07ns

Different letters in the row indicate significant differences ($p \leq 0.05$), and 'ns' indicates nonsignificant according to Tukey's test. T0 = Roblan® LED T8, 18W. T1 = Valoya® L18 AP67 Milky. T2 = Valoya® L18 NS1, 18W. T3 = Valoya® L18 AP673L Milky.

The heights of rooted stem cuttings showed a significant difference (Figure 2A). The stem cuttings rooted under T1 were 25% taller than others (Table 2). On the other hand, using the same luminous spectra in *Salvia fruticosa* plants, the heights were the same with no statistical difference (Bantis & Radoglou, 2019). When observing the spectral composition of the T1 light, a greater presence of red (R) and far-red (FR) spectra was observed. FR activates the specific phytochromes (PHY) responsible for the plant's shade avoidance, resulting in a hormonal balance supporting plant elongation when plants grow towards the light source (Gelderen et al., 2018), as was observed in rooted stem cuttings under T1.

After the rooting phase, the averages of fresh and dry masses did not differ for leaves, stems, and roots (Table 2), nor was there an effect on the root-to-shoot ratio (R/S). The R/S ratio indicates whether stem cutting will have enough roots to absorb water and nutrients, support the shoot, and ensure the good development of the future plant (Bantis, Ouzounis, & Radoglou, 2016); if this difference does not occur, all seedlings have the same chance of survival after transplanting.

After growing phase, the elongation of the lavender plants under T1 became more evident (Figure 2B), with a height 55% taller than the T0 plants. It was also evident by an increase in internodes (Table 3). Visually, the plants grown under T3 had a more compact canopy (Figure 2B), similar to the observations for *Lippia filifolia* plants which exhibited more branches, a more compact canopy, and greater accumulation of plant biomass when grown in similar proportions of blue and red spectra (Chaves et al., 2020).

After the growing phase, light spectra were observed to impact plant mass production (Table 3). The average leaf fresh mass of plants under T2 and T3 was 31% higher than that observed under T0. Although the plants under T1 were taller, the leaf fresh mass was less than the plants under T2 and T3. Some authors suggest that the accumulation of fresh mass is inversely proportional to plant height (Chaves et al., 2020). Regarding fresh stem mass, all treatments showed higher results than those of T0 plants. The highest average root fresh mass production was in plants under T3, which was 48% higher than that observed in plants under T0. Higher leaf production generally provides better carbohydrate partitioning for the roots (Gelderen et al., 2018), and can be seen in T3 plants. In this study, the white LED used in T0 was not a good light source for fresh mass production;

the same scenario was observed in the fresh mass production of *Ocimum basilicum* under white LED by Frąszczak, Golcz, Zawirska-Wojtasiak, and Janowska (2014). Usually, plants tend to produce less fresh mass when subjected to monochromatic spectra, with the best results obtained in combined spectra (Li et al., 2020). Even with the variations observed in the dry mass averages, it is possible to notice that plants cultivated under T3 presented higher average values than those produced under T0. It was possible to observe higher dry mass averages of 40%, 59%, and 45% for leaves, stems, and roots, respectively, in T3 than in T0 (Table 3).

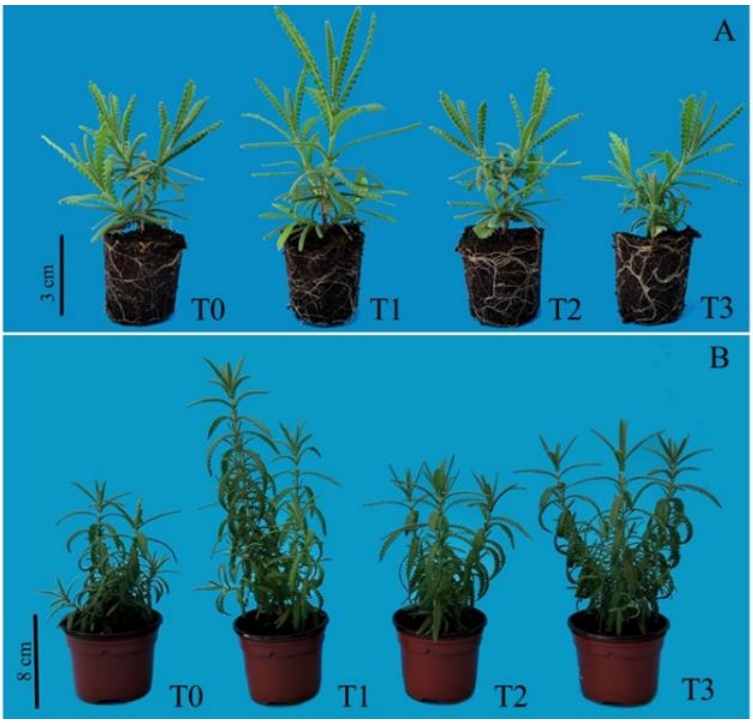

Figure 2. Rooted stem cuttings of *Lavandula dentata* after 60 days, on the rooting phase (A); and *Lavandula dentata* plants after 60 days on the growing phase (B) under light treatments: T0 = Roblan® LED T8 18W; T1 = Valoya® L18 AP67 Milky; T2 = Valoya® L18 NS1 18W; T3 = Valoya® L18 AP673L Milky.

Table 3. Height (cm); internodes length (mm); stem diameter (mm); fresh mass and dry masses of leaves, stem and root (mg·plant^{-1}); essential oil yield (EO, %); electricity use efficiency (EUE, mg·kW^{-1}); light use efficiency (LUE, mg·mol^{-1}); illuminance use efficiency (IUE, mg·lm^{-1}); and water use efficiency (WUE, g·L^{-1}) of *Lavandula dentata* plants after 60 days of growing phase, under light treatments.

	T0	T1	T2	T3
Height	15.0 ± 0.8c	23.3 ± 0.5a	17.3 ± 0.5b	17.5 ± 0.6b
Internodes' length	7.8 ± 1.1b	12.0 ± 0.7a	9.1 ± 0.7b	9.3 ± 0.5b
Stem diameter	1.4 ± 0.1ab	1.2 ± 0.2b	1.5 ± 0.2ab	1.6 ± 0.2a
Fresh mass				
Leaves	7.0 ± 0.5b	7.8 ± 0.6b	9.1 ± 0.3a	9.2 ± 0.4a
Stems	1.1 ± 0.1b	1.7 ± 0.2a	1.7 ± 0.1a	1.8 ± 0.1a
Roots	3.24 ± 0.09c	3.24 ± 0.13c	3.52 ± 0.13b	4.81 ± 0.11a
Dry mass				
Leaves	1.14 ± 0.06c	1.40 ± 0.14b	1.56 ± 0.10ab	1.63 ± 0.08a
Stems	0.27 ± 0.02c	0.45 ± 0.04a	0.36 ± 0.02b	0.41 ± 0.02ab
Roots	0.33 ± 0.03b	0.36 ± 0.04b	0.44 ± 0.04a	0.51 ± 0.01a
EO	0.27 ± 0.03ns	0.26 ± 0.01ns	0.24 ± 0.04ns	0.29 ± 0.04ns
EUE	0.80 ± 0.04c	1.02 ± 0.08b	1.10 ± 0.06ab	1.18 ± 0.04a
LUE	127.0 ± 6.9d	232.1 ± 17.1a	150.7 ± 8.4c	198.5 ± 6.5b
IUE	20.3 ± 1.1c	47.1 ± 3.5a	24.2 ± 1.3bc	38.3 ± 1.2b
WUE	8.9 ± 0.5b	9.0 ± 0.5b	9.7 ± 0.4b	11.3 ± 0.4a

Different letters in the row indicate significant differences ($P \leq 0.05$), and 'ns' indicates nonsignificant according to Tukey's test. T0 = Roblan® LED T8 18W. T1 = Valoya® L18 AP67 Milky. T2 = Valoya® L18 NS1 18W. T3 = Valoya® L18 AP673L Milky.

When analyzing the rooting and growing phases, it was observed that T1 treatment showed better results in rooting, while T3 presented plants with a more uniform canopy. Understanding how spectra can influence each stage of the plant cycle allows the establishment of forms for a more dynamic manipulation of light during cultivation (Spalholz et al., 2020).

The yield of essential oils (EO) extracted at the end of the growing phase did not show any difference, with the average remaining at 0.27% (Table 3). Some authors suggest that luminous spectra may influence plant mass production but not the EO, with luminous intensity more related to EO yield values (Lima et al., 2017; Alsahli, 2019). In the species, *Lippia alba*, *Mentha spicata*, and *Petroselinum crispum*, differences in the luminous spectra did not alter the EO, but the spectra did influence the EO chemicals (Alves et al., 2018; Ascrizzi, Fraternale, & Flamini, 2018; Nguyen & Saleh, 2019).

The amount of nutrient solution consumed differed according to the luminous spectra because the extent of rooting was more evident in the growing phase (Table 4). At the end of the growing phase, all plants grown under T0 consumed fewer amounts of solution (Table 4). The drainage percentages, both in rooting and growing phases, are commonly reported for soilless open systems (Rodríguez et al., 2014).

Table 4. Nutrient solution consumption (mL·plant^{-1}); drainage (%); drainage pH and electric conductivity (EC, dS·m^{-1}); leached nitrate and potassium (mg·plant^{-1}) obtained from the cultivation of *Lavandula dentata* plants under light treatments.

		T0	T1	T2	T3
Nutrient solution consumption	Rooting phase	107.6 ± 7.0ab	115.8 ± 5.2a	108.2 ± 7.6ab	100.2 ± 3.8b
	Growing phase	1269 ± 11c	1423 ± 6ab	1492 ± 29a	1404 ± 73b
Drainage	Rooting phase	26 ± 1ns	27 ± 1ns	26 ± 1ns	26 ± 1ns
	Growing phase	23 ± 2ns	22 ± 2ns	23 ± 1ns	23 ± 2ns
pH	Rooting phase	6.60 ± 0.03a	6.31 ± 0.05c	6.46 ± 0.04b	6.56 ± 0.04a
	Growing phase	6.07 ± 0.02ab	6.02 ± 0.03b	5.99 ± 0.03b	6.10 ± 0.06a
EC	Rooting phase	4.94 ± 0.44ns	5.22 ± 0.18ns	4.90 ± 0.47ns	4.50 ± 0.11ns
	Growing phase	5.98 ± 0.36ns	5.37 ± 0.56ns	5.91 ± 0.49ns	5.22 ± 0.39ns
NO_3^- leached	Rooting phase	39.87 ± 0.98ns	38.80 ± 1.07ns	36.33 ± 3.63ns	39.27 ± 2.46ns
	Growing phase	815.7 ± 22.4a	491.1 ± 5.6c	706.7 ± 14.3b	509.5 ± 6.8c
K^+ leached	Rooting phase	18.77 ± 1.76ns	21.17 ± 0.80ns	18.08 ± 1.30ns	20.86 ± 3.25ns
	Growing phase	436.1 ± 13.5a	310.1 ± 16.1c	365.5 ± 12.9b	228.2 ± 8.4d

Different letters in the row indicate significant differences ($P \leq 0.05$), and 'ns' indicates nonsignificant according to Tukey's test. T0 = Roblan® LED T8, 18W. T1 = Valoya® L18 AP67 Milky. T2 = Valoya® L18 NS1, 18W. T3 = Valoya® L18 AP673L Milky.

The leaching of nutrients obtained from the drainage was different in each analyzed phase. No differences were observed in the nutrients leached from the stem cuttings during the rooting phase. The average value of leached nitrates (NO_3^-) was 38.5 mg·stem cutting^{-1}, and that of leached potassium (K^+) was 19.7 mg·stem cutting^{-1} (Table 4).

The leached nutrients measured in the drainage collected during the growing phase differed depending on the studied light spectra. The highest values of NO_3^- leached were in the drainage of the plants grown at T0. The plants with the least leached NO_3^- were grown under the T1 and T3 treatments, with a reduction of 38%, that is, a difference of 315 mg·plant^{-1} of NO_3^- leached in relation to T0. Likewise, the influence of light on K^+ leaching was observed. The highest average leached potassium was observed in the drainage of plants grown under T0, while the lowest averages were in T3, which presented a reduction of 48% (Table 4). When analyzing the drainage of *Rosmarinus officinalis* plants grown in a greenhouse using similar substrate and nutrient solutions, the leached nitrate and potassium values were similar to those found in T3 (García-Caparrós et al., 2018). This indicates that the spectral composition of T3 causes the same nutritional responses as those observed in the greenhouse under sunlight.

Some evaluated parameters allowed us to estimate the resource use efficiency. The water use efficiency (WUE) was the same among all four treatments at the end of the rooting phase. On average, each liter of water applied produced 11.6 g of fresh material during the rooting phase (Table 2). During the growing phase, the plants grown under T3 were 23% more efficient in water use than those under other treatments (Table 3). Normally, soilless cultivation systems show higher water use efficiency than other productive systems (Gruda, 2019). However, when the light quality is adjusted to the best responses of the plant, the cultivation system becomes even more efficient in relation to the spent resources such as water and nutritional resources (He et al., 2020).

The efficiency of plant production in relation to artificial light can be calculated in several ways; by considering electricity use, the number of moles emitted through the photosynthetic flux, or the illuminance

of each lamp used. Regardless of the method used to calculate efficiency with respect to artificial light, we are looking for parameters to make the best decision regarding which luminous resource to adopt (Park & Runkle, 2018; Miler et al., 2019; Yang, He, Niu, Zhou, & Qu, 2019). After the rooting phase, the evaluated light use efficiency (LUE) and illuminance (IUE) were influenced by the light treatments (Table 2). The LUE mean values of the stem cuttings rooted under T1 showed an increase of 82% compared to the other treatments, while IUE values were 110% higher than stem cuttings rooted under T0. The mean values of electricity use efficiency (EUE) were similar, producing an average of 243 mg of plant material for each kW spent during the rooting phase (Table 2).

After the growing phase, it was observed that the parameters used to measure luminous efficiency differed according to each treatment. The LUE and IUE values of the plants grown under T1 were 82 and 132%, respectively, with higher averages observed in T0 plants (Table 3). However, the observed EUE averages of T2 and T3 were 43% higher than the control, producing 1.14 grams of fresh mass per kW used at the end of the growing phase. EUE is a parameter that directly reflects production costs, with higher EUE values resulting in greater financial savings (Miler et al., 2019).

When analyzing the levels of six macronutrients in the plants obtained after the growing phase, only magnesium did not show any significant change in the applied treatments, with a general average of 4.2 $g \cdot kg^{-1}$ (Table 5). An order of accumulation of these nutrients was determined when observing the variations between nutrient levels in all treatments, with potassium being absorbed in greater quantity, followed by nitrogen, calcium, phosphorus, magnesium, and sulfur in less quantity, similar to that observed in *L. dentata* by Fascella et al. (2020).

Table 5. Levels of macronutrients ($g \cdot kg^{-1}$): nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S). Nutrient use efficiency (NUE) and nutrient uptake efficiency (NUpE) of *Lavandula dentata* plants after 60 days on growing phase, under light treatments.

	T0	T1	T2	T3
Levels of macronutrients				
N	26.27 ± 1.31a	23.08 ± 0.73b	22.25 ± 0.48b	23.50 ± 1.18b
P	6.09 ± 0.23a	5.18 ± 0.25c	5.53 ± 0.24bc	5.82 ± 0.24ab
K	44.94 ± 0.62a	42.90 ± 1.28ab	42.58 ± 0.59b	43.60 ± 1.56ab
Ca	11.84 ± 0.25b	11.90 ± 0.78ab	12.48 ± 0.92ab	13.13 ± 0.05a
Mg	4.40 ± 0.36ns	4.04 ± 0.21ns	4.12 ± 0.07ns	4.25 ± 0.16ns
S	3.25 ± 0.12b	3.18 ± 0.16b	3.34 ± 0.07ab	3.51 ± 0.09b
NUE				
N	5.2 ± 0.5b	6.6 ± 0.6a	6.4 ± 0.4a	7.1 ± 0.6a
P	17.2 ± 1.6b	21.9 ± 2.0a	21.3 ± 1.2a	23.4 ± 2.0a
K	2.9 ± 0.3b	3.7 ± 0.3a	3.6 ± 0.2a	3.9 ± 0.3a
Ca	5.3 ± 0.5b	6.8 ± 0.6a	6.6 ± 0.4a	7.2 ± 0.6a
Mg	32.8 ± 3.1b	41.9 ± 3.8a	40.7 ± 2.2a	44.8 ± 3.8a
S	9.9 ± 0.9b	12.7 ± 1.2a	12.4 ± 0.7a	13.6 ± 1.2a
NUpE				
N	0.128 ± 0.011b	0.144 ± 0.008b	0.145 ± 0.006b	0.172 ± 0.008a
P	0.098 ± 0.005c	0.114 ± 0.011b	0.118 ± 0.011b	0.143 ± 0.008a
K	0.131 ± 0.013b	0.160 ± 0.012a	0.154 ± 0.010ab	0.173 ± 0.016a
Ca	0.063 ± 0.006c	0.081 ± 0.004b	0.082 ± 0.008ab	0.095 ± 0.008a
Mg	0.134 ± 0.010c	0.169 ± 0.012b	0.168 ± 0.011b	0.196 ± 0.012a
S	0.031 ± 0.002c	0.041 ± 0.001b	0.040 ± 0.002b	0.049 ± 0.003a

Different letters in the row indicate significant differences ($p \leq 0.05$), and 'ns' indicates nonsignificant according to Tukey's test. T0 = Roblan® LED T8 18W. T1 = Valoya® L18 AP67 Milky. T2 = Valoya® L18 NS1 18W. T3 = Valoya® L18 AP673L Milky.

The nutrient use efficiency (NUE), which is related to plant mass produced using the amount of applied nutrients, differed according to the light treatments. The T0 treatment produced plants with the lowest NUE values, with results varying from 28 to 30% lower than those observed in NUE of plants from other treatments (Table 5). These results demonstrate that T0 light was the least efficient in producing vegetal mass in relation to the applied nutrients. The nutrient uptake efficiency (NUpE) is the relation between the amount of nutrients in the shoot and the amount of applied nutrients. Plants grown under T3 showed higher NUpE values for N, P, Mg, and S (Table 5). Initially, plants under T0 showed higher nutritional levels (Table 5); however, they produced the lowest average plant mass (Table 3). This combination, observed in T0 plants, with higher nutritional levels and less mass production, is an example of a luxury consumption of nutrients, while in the other treatments, the plants had lower nutritional contents (Table 5) and higher production of vegetable mass (Table 3), exemplifying the so-called nutrient dilution effect (Hawkesford et al., 2012).

Conclusion

The light spectrum supplied by Valoya® L18 AP67 Milky (T1) during *L. dentata* L. stem cuttings rooting provided larger plants and had no difference in root-to-shoot ratio from plants under other treatments. This suggests that this spectrum range should be used for the stem cutting rooting phase. At the end of the growing phase, *L. dentata* plants grown under the spectrum range supplied by Valoya® L18 AP673L Milky (T3) showed better biomass production and better canopy visual aspect. This spectrum range also showed better use of electricity, water, and nutrients, which suggests this spectrum should be used for the growing phase.

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